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Of Interest to Publishers

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Measuring Efficiency in Manufacturing on a Basis of Profit

Read at the regular monthly Meeting of the
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Of Interest to Editors

The following paper was prepared by request for presentation before The American Society of Mechanical Engineers. It illustrates the development by the author, who is Manager of the Waverly Press, of organization methods in applying the principles of scientific management as taught by Mr. Frederick W. Taylor and his followers. As Mr. Charles B. Going, editor of the *Engineering Magazine*, states in his discussion, "While the fundamental principle of profit as a basis for measuring efficiency of production is new and important, ... the paper does not distinguish any new factors or combination of factors, but it proposes a new datum from which to measure the total results . . . . likely to be influential because *reform is much more likely to be stimulated by a realization of loss than by the belief that profits have been merely reduced.*"

It is not intended to advance the idea that the *one* object of business is profit, but to emphasize that *without* profit business cannot exist. With complete and accurate knowledge of cost of production full value of product and service can be delivered to each individual customer on every order. The results of such methods are to maintain an equal rate of profit on each order, instead of an average profit on the total business, with some orders showing a loss and some an excessive profit, and makes possible a minimum charge to the customer for the work done.

This subject is indirectly of interest to you as a publisher, an editor, or an author, inasmuch as it shows conclusively that an organization developed and operated under such a system is capable of producing a higher standard of product, a higher degree of service, and a greater value to its customers in both of these important lines of effort.

With the development of this system in the organization of our shop the good results that can be obtained are already apparent, and are continually increasing. We are producing a high standard of workmanship, we are operating under a much more positive system of scheduling which gives prompt service, and the real value of the product of our press is greater than it ever has been before, and is unsurpassed, if equalled, by that of any of our competitors. We have demonstrated this to the satisfaction of others, and we are prepared to show you.

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MEASURING EFFICIENCY IN MANUFACTURING ON A BASIS OF PROFIT

Rankin's definition of efficiency is: "The ratio of useful work produced to the energy expended," a very reliable basis for determining the efficiency of a steam engine or any power producing machine or equipment. The general definition of efficiency given in Webster's Dictionary is "effectiveness or the power to produce results."

The term *results* as used in connection with business is synonymous with gain. The efficiency of a business or industrial enterprise is rated in proportion to the percentage of profit earned.

In the application of the term efficiency to the management of a business or an industrial enterprise, it becomes what might be called relative or comparative efficiency; that is, the work of an operative or a machine is efficient to a degree, as compared with an established standard or ideal of production.

Both the engineer and the accountant in their work of measuring and recording production, attempt to measure and record efficiency, but the methods which they employ do not give accurate and complete results. The subject of cost accountancy has received during recent years a great deal of attention in all branches of industrial enterprise. The determination of hour cost has been the object of the accountant. Hour cost without a means of measuring and recording production still retains the element of guess-work in that the product per hour has to be estimated.

This is the fundamental weakness of the accepted systems of cost accountancy in general use today. As the cost accountant studies hour cost it is natural that he should in recording efficiency adopt the productive or chargeable hour as the basis for determining the efficiency of an operative or machine. It will suffice here to point out the unreliability of efficiency records that

are obtained on such a basis. For example: A machine may be running ten hours on productive time, and if the work day is ten hours, the cost accountant rates the efficiency of the machine at 100 per cent; but no cognizance is taken of the amount produced per hour. In other words, the accountant's percentage of efficiency is the ratio between the actual hours of production charged to an order, and the total hours of the work period, without taking into consideration the amount produced in the period.

The engineer in studying the problems of management has adopted mechanical production as the basis of his work. He has established, after careful scientific investigation, what is usually termed a standard of production, that is, the amount that should be produced in a given time. In determining this standard a standard unit of measurement for each element of production must be established. This standard, complemented by a system of recording the production of each operative and machine and on each operation enables him to find the productive efficiency on each operation and of each operative or machine by taking the ratio between the actual amount produced and what has been established as the standard amount to be produced. While this is an advance over the accountant's method, still it does not give a true record of efficiency.

Neither accountants nor engineers by their present independent methods and their different units of measurement get the true record of efficiency in terms of profit and loss. True efficiency is the ratio between the percentage of *profit* on the cost of what is actually produced and what would be the profit if the standard amount of work were produced.

Veblen states in his Theory of Business Enterprise that the all-dominating issue in business is the question of gain and loss. Gain and loss is a question of accounting, and accounts are kept in terms of the monetary unit, not in terms of livelihood, not in terms of serviceability or vendability of the goods, nor in terms of the mechanical or productive efficiency of the industrial or commercial plant. Since the efficiency of a business is finally determined in terms of profit and loss, every individual department of that business should be determined on the same basis,

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and every unit of production, either operative or machine, should be determined and expressed in the same terms.

Every one familiar with the conditions of industrial enterprise knows that an increase of productive hours does not necessarily mean profit. Going a step further, increased production per hour, or even full or maximum production of a machine or factory does not necessarily mean profit. Still, as profit is the only true test of efficiency, then the efficiency of a plant or its component parts should be reckoned in terms of profit and loss, and not in terms of mechanical production or in terms of productive hours. To illustrate, an example may be taken of a very elementary form of business, that of shoveling coal, in which the operatives are hired by the hour. According to the system of the accountant for determining efficiency, if the operative shoveled coal without interruption during the full period of work, irrespective of the amount he shoveled, he would be rated 100 per cent efficient. A method for determining efficiency by which a rating of 100 per cent would stand for variable amounts of product, and represent either a profit or loss, is certainly unreliable to say the least.

The engineer in handling the problem would, after the proper selection of the shovel and standardization of working conditions, determine the standard amount to be shoveled in an hour. That, let us say, is a ton. Then the man who shoveled this standard amount would be rated 100 per cent efficient.

To test this method of determining efficiency, suppose that the operative's wage is 50 cents per hour, that the total expense burden of the business amounts to 50 cents per hour, and that the shoveling of coal is sold at $1.50 per ton. This would bring a profit of 50 cents per hour, equal to 50 per cent of cost equal 100 per cent efficiency, when the standard or full amount is shoveled by the operative. If an operative shovels only half a ton per hour, he will, according to the engineer's method of determining efficiency, be rated as a 50 per cent efficient workman. Now, let us consider the question of cost and profit in this case. The wage for the operative becomes $1 per ton, the expense burden $1 per ton, a total cost of $2 per ton. This

represents a loss of 50 cents on each ton, instead of a profit of 50 cents or −25 per cent of cost instead of plus 50 per cent, and shows the actual efficiency to be minus 50 per cent. Eminent engineers who have made a study of management and efficiency have said that cost of production has nothing to do with the selling price. That is true to a certain extent, because the margin of profit, which is the difference between cost and the selling price, can be figured according to the demands of the situation or the conditions of the sale. That is to say, it may be expedient to reduce the margin of profit in order to close a large contract, and thus save a greater loss in fixed expenses, if there is not sufficient work on hand for the facilities of the plant, or it may be advisable to reduce the margin of profit in order to obtain an entering wedge into new territory. Profit is controlled also by such trade conditions as competition, supply and demand, etc. Although variation in the margin of profit changes the percentage of efficiency, still efficiency, when determined on a basis of profit and loss, shows to the management results which give the true value of each unit of production in the organization, and which bring to the surface the necessity of more efficient work when the margin of profit is low. The greater the margin of profit a commodity will stand over and above the cost of production, the more inefficiently the work may be handled without wiping out the gain completely. Under a correct system of measuring, *when the efficiency of an operative, of a machine, or of any operation is at zero, it is a signal that no profit is being made.*

To illustrate, take for example the case of the common hen. All have heard probably of the 200-egg hen, the hen that lays 200 eggs in 365 days. This is the standard set by breeders of the laying machine. Suppose that the average market price of eggs during the year is two cents each, making the gross return from a standard hen $4. The feed for this hen (which corresponds to the wages of the workman) is one-half cent a day, equaling $1.83 a year. All other expenses, such as gathering the eggs, cleaning the coops, marketing the product, etc., amount, we will say, to $0.94 a year, giving a total expense of $2.77. This leaves a net profit of $1.23 on what we will term a standard hen.

A hen that lays 100 eggs a year would, according to the engineer's method of determining efficiency, be rated at 50 per cent. Now let us see what becomes of her when her efficiency is determined on a basis of profit and loss. Her product is worth $2, while her expense remains the same, $2.77, therefore, she is kept at a loss of $0.77 and her efficiency on a basis of profit and loss is approximately minus 62 per cent. It is not difficult to imagine what would become of such a hen after her true worth was known. She would probably lose her head.

The machine process, the basis of all modern industrial enterprise, is a comparatively new element in business. Not very long ago, production was for livelihood only, and not for profit in the sense of accumulating wealth. A printer was a printer to make a living, likewise the carpenter, and so in all lines of trade; but the advent of the machine revolutionized production and placed industrial enterprise on a footing fully equal in volume and value to that of trade and commerce.

Accountancy as generally taught and practised was designed for the business of trading, in which merchandise is bought according to certain standard units of measurement, and sold on the same basis. The function of bookkeeping, according to such systems, is to record the transactions of business, keeping a record of the items of expense, and distributing the same as a burden of expense on the merchandise handled. In industrial enterprise, merchandise is *bought* according to certain established standards of measurements, the same as in trade, *but* it is not *sold* on the same basis. It is converted into other forms of production by the use of labor and machinery. Labor is purchased by the hour and is combined with merchandise, but as there have been no standards of measurements of production of labor established, true cost of production cannot be, in any sense, accurately predetermined.

Accountants take the position that it is not their function to establish standards of measurements. Even accepting this statement, it does not seem reasonable for them to establish a system of accountancy based on false premises. In other words, the determination of hour cost is only elementary. It is true that

it is the first step toward obtaining accurate cost; but without the establishing of standard units of measurement of production in an industrial enterprise, and a system of recording production, true unit costs of the elements of production cannot be predetermined, but can only be obtained after the work on an order is completed, and this is always too late to prevent a loss. A merchant might as well buy a carload of sugar, and in selling it by the pound guess at the weight. By keeping a record of his receipts from the sale of the sugar, he would find out after the carload had been sold whether he had made a profit or not.

In all industrial enterprise practically the same condition exists in the purchase of labor. It is bought by the hour, but the production per hour is estimated or guessed at. Therefore, it is not putting it too strongly to state that the work of the accountant has not kept pace with the development of industrial enterprise, and that the ordinary systems of bookkeeping are inadequate to the requirements of the same.

The engineer in his work of establishing standard units for measuring production and in recording production is doing good work for the industrial enterprise. The inaccuracy of the results he obtains is due to the fact that his method of measuring efficiency is based on mechanical production, which is not the true unit of measurement of industrial or manufacturing efficiency, and, as has been shown previously, does not give true records of efficiency. Increased production usually increases the efficiency of an establishment by increasing profits, but it does not necessarily follow that such is the result.

This is the weakness of the situation. The accountant is not sufficiently trained in the technicalities of industrial conditions, and the engineer has not sufficient knowledge of the technicalities of accountancy. These two departments of manufacturing business should be brought into close relationship, and both should work on the same basis of measurement in recording their work and results. If this is done, the work of the accountant and that of the engineer will both be simplified and materially cheapened, and the records obtained will be of much greater value to the organization. For example, when the engineer determines

on a new method of operation designed to increase production, the full value of his work will be determined by true efficiency records as a definite profit or loss, expressed in dollars and cents and not in mere increased mechanical production.

The accountant will probably say that such a system involves a great deal of bookkeeping. That may be; but is it not just as important to have a standard for measuring production, and a method of recording production in an industrial enterprise, as it is to have the same means of measuring goods bought and sold in ordinary business or trade?

A merchant could not exist very long, if his business were conducted on a basis which was without the means of measuring his purchases and sales. It is true that many years have been spent in trade. Probably the reasons why standards of measurement have not been attempted in industrial enterprise is because industrial enterprise, comparatively speaking, is in its infancy, and also because there are more standards to establish. But if it is a basic necessity which has been brought to the surface more forcibly in recent years on account of closer competition and smaller margins of profit, then the sooner the task of establishing these standards in all lines of work is undertaken, the greater will be the returns to those who have their money invested in the enterprise, and to the world at large. There is certainly a broad economic problem involved in the situation.

To combine the work of the engineer and accountant in applying the general principles of what is termed "Man and Machine Records" to the operation and management of business, tradition must be set aside, and new methods and supplementary principles must be accepted by both. It is possible that these methods at first sight may appear absurd when considered in the light of established usage, but as expedients they will be necessary. They can be made to produce records of cost and efficiency which will be accurate and reliable, even if not in accordance with accepted practice, and the results will certainly justify the means. To repeat, the term *results* as used in connection with business is synonymous with gain: then the true efficiency of business or industrial enterprise must be rated in proportion to the per-

centage of profit earned. Therefore, the engineer and accountant must learn to think in terms of profit and loss and not in terms of production or hour cost.

It has been shown: (*a*) that the true measure of efficiency in manufacturing must be recorded in terms of profit, not in terms of productive hours, nor in terms of amount produced; (*b*) that some definite standard of profit must be established; and (*c*) that any profit between actual cost and the established standard profit shows efficiency varying between zero and 100 per cent. A loss is recorded as minus efficiency. Zero efficiency indicates that actual cost has been covered. One hundred per cent efficiency means that the maximum amount of profit is earned.

Is it possible to combine the work of engineer and accountant so as to record efficiency in terms of gain, in order that each step in production may be accurately measured instead of waiting until all the steps have been taken to get at the profit? The answer to this question is that such methods are now being successfully introduced.

Every business of manufacturing can be divided into a number of elementary operations and individual units. Each one of the simple operations is called an *element* of production. Cleaning the coops, gathering the eggs, feeding the hens are elements of production in the case of the egg business before referred to. Any individual part of an organization that produces, whether operative or machine, is a *unit* of production. The hen and the boy who feeds her are both units of production.

First, it is necessary to establish the actual cost of each simple operation or element. The cost of each job, take or order, can then be determined.

Second, it is necessary to establish, (*a*) the standard production for each element, that is, the maximum production possible to attain when working under standard conditions, and (*b*) the standard for each unit, individual or machine. After this has been done, the profit that should be earned under such conditions can readily be determined, and it becomes the standard profit. This standard profit is taken as the basis for determin-

ing efficiency. Thus, having established the standards for measuring production and having recorded the amounts produced by each element and unit, the actual profit earned can be determined. The efficiency is the ratio between the percentage of actual profit and the percentage of standard profit.

The efficiency of a unit can be made up from the efficiency of several elements, depending upon the different kinds of work that an operative or machine is handling. The efficiency of an element can be made up from the efficiency of a number of operatives or machines. To illustrate, a workman in a machine shop being a unit of production might work at a lathe half a day at an efficiency of 80 per cent, the other half working at the bench at an efficiency of 60 per cent. Then his efficiency as a unit of production for the day would be the average between the two, or 70 per cent. The lathe work on a given size machine, being an element of production, may represent the work of one or more operatives. The first may show an efficiency of 80 per cent, another 50 per cent, and the third 70 per cent. So the efficiency of the element would be the average of all.

In establishing the standards of production and profits on the elements of production, it is necessary to establish standard costs of each element. In order to determine the actual cost[1] at any time, it is necessary only to divide the standard cost by the percentage of efficiency of the element, and actual cost is obtained. For example, if the standard cost of an operative or operation be $1, the actual cost of operative or operation marked 50 per cent efficient will be $\frac{1.00,}{0.50}$ or $2. Thus it will be seen that the determination of cost becomes a very simple part of accountancy, when the work of the engineer is combined with that of the accountant.

In the best recognized cost accounting practice, the selling price is obtained in the following manner: First the total cost of manufacture is found, then the general administrative and sales expenses are added, and to this result is added the percentage of profit to be earned.

[1] Emerson, Harrington, Twelve Principles of Efficiency.

For convenience and simplicity it is recommended that *cost* shall include all items of expense, *and that the normal profit which is to be earned when working under standard conditions shall be treated as an expense and included in the cost*, just in the same way as interest on the plant investment, surplus, and working capital and loss through depreciation are considered items of expense. On first thought to treat profit as an expense may be considered absurd, but if we are to determine efficiency on a basis of profit and loss, to do so will simplify the process very much.

On such a basis there are three sources of loss to be considered: First, the loss sustained by a workman or machine consuming too much time; second, the loss sustained by idle equipment, due to absence of an operative from work, lack of work, accidents, etc.; and third, the loss through actual spoilage. Now, if loss through inefficiency is to be considered as a possible profit, as it most certainly should be, then the profit which would have been earned on such lost time and material must also be considered. For this purpose, the adoption of the machine rate process as presented by Hamilton Church is necessary.[2] When the expectant profit is considered as an item of expense, and is included in the machine rate, then such loss is taken care of automatically. Further, the machine rate should be based on ideal or standard conditions and should carry all items of expense, including the expectant profit, exclusive, however, of labor.

To illustrate the loss incurred by taking too much time we will refer again to the example of the hen. The reason why a hen lays only 200 eggs a year is because there is a molting season, and also a period when there is a desire in most breeds to set. During these periods eggs are not produced, so if the periods of molting and setting are prolonged there is a loss in production due to taking too much time.

To illustrate the loss sustained by idle equipment: Suppose that the hen is turned loose in the neighbor's garden and that she lays her eggs in the neighbor's barn. The expense, exclu-

[2] Church, Hamilton, Expense Burden.

sive of the wage, still goes on without production and the profit thereon. The equipment is there for taking care of her, she comes home to roost, the coops have to be cleaned, etc.

To illustrate the loss through spoilage: The hen may lay the eggs but break them in the nest. The expense and wage still go on, but the production is lost and the profit thereon. Therefore to determine the true value of the hen, records should be kept only of the eggs laid at home, and from these the eggs broken in the nest should be deducted.

The value of similar records to an industrial management can be readily seen.

In the first case of loss, the excess hours should be charged at the full rate of cost including the normal profit and labor. In the second case, the time lost through idle equipment should be charged at the machine rate, and without the labor rate. In the third case, the hours lost through the spoilage of work should be charged at the final cost rate including labor and profit, plus the merchandise spoiled, to which should be added the expectant profit thereon.

By totaling these three items of loss whenever they occur and substracting the sum from the profit on the number of standard hours produced, the result will be the actual profit or loss on the operative or machine for the given period. The ratio between this amount and the established standard profit for the same period will give the true rate of efficiency.

By establishing standards of production and profit of each unit and element of production, the standard of the whole organization will be the total of its standard units, and the efficiency of the whole will be the total of all of its units.

By including the normal profit to be earned under standard conditions in the item of cost, the management can determine at any time the percentage and amount of profit being earned. For example, allowing everything in an organization to be 100 per cent efficient, if the standard profit be 20 per cent, then if the total efficiency is 50 per cent the profit earned is 10 per cent. If the amount of business done during the period is $100,000 the profit earned is $10,000. When the efficiency of the whole

or any part becomes zero there is no profit; when it becomes minus, there is a loss.

This plan enables the management to know positively how the organization is running. It not only brings to the surface the unprofitable units of production, but keeps them there constantly, showing absolutely and positively that they are unprofitable and to what extent they are.

One method by which this plan can be practically put in use by the bookkeeper is to open an account for each cause of inefficiency and charge the loss sustained thereby to this account, and thus carry it through the profit and loss account. As an illustration, suppose that a grain merchant located in Baltimore buys 100,000 bushels of spring wheat which is shipped to Baltimore and stored in a grain elevator. While in transit and in storage the grain becomes seasoned and dries out. When it is sold, it is found that it has shrunk to 99,000 bushels. This shrinkage would be taken care of by opening a shrinkage account, and the loss sustained thereby would be a direct loss to the business. The grain merchant would be interested not only in knowing the loss through shrinkage on each lot of wheat, but also on the other grains he handled, the barley, corn, rye, etc., and the total loss from shrinkage on all. As well say that loss through shrinkage cannot exist, as that loss through inefficiency cannot exist. It does exist, and can be taken care of from a bookkeeping standpoint, provided of course, that standard units of measurement of production of labor are established, and the actual production of labor is measured and recorded.

Another method, and probably a better one, for an industrial enterprise, is to treat the loss through inefficiency as a supplementary rate of cost. To do this, the machine rate of cost must be established, as previously explained, on standard production, and each cause of loss through inefficiency carried as a separate supplementary rate, which, when added to the basic machine rate and labor cost, will give the total cost. This method will show at all times loss through inefficiency, if any, for as many divisions or causes as it is found expedient to establish, and it has the advantage over the first method in that it is carried on

the cost record sheet as a definite amount of loss expressed in dollars and cents on each productive hour, keeping constantly before the management the inefficiency of each department.

Naturally the thought will come that there are conditions which affect production and profit for which the workman is not responsible. This is true, and such loss should not be charged against the efficiency record of the operative or machine.

One of the fundamental principles which is accepted by all accountants is that all items of expense should be charged directly to the department or production factor whenever it is possible to do so; that there should be no common dumping ground, so to speak, for expense items to be distributed on a percentge or some similar basis. In the same manner all inefficiency can be chargeable to someone; it may be to the management, to the sales department, to the planning department, or it may be necessary, in the event of fire or cyclone, to charge it to the dispensation of Providence.

It must be accepted as a basic truth that all loss through inefficiency which represents a potential or possible profit in the enterprise is chargeable to someone. If such items are reckoned in terms of profit and loss expressed in the monetary unit of measurement, they can be carried through the general books of the concern in accounts opened for that purpose. When a statement of the business is taken, the balance sheet will show not only the profit or loss of the business as a whole, but it will show the loss through inefficiency, a possible profit, which should have been earned. Further, in the departmental statement, this loss through inefficiency will be shown, and it can be traced to each production center of a department and to each individual operative and machine, if desired. The records will show then not only the profit as a whole, and the potential profit, which is the loss through inefficiency, but it will direct the loss to each individual or unit of production of the whole organization.

Without a means of measuring efficiency in manufacturing it is impossible to locate the units and elements that are inefficient. Therefore the profits of the efficient units and elements are lessened by the inefficient, and may be entirely neutralized. When the

hen does not lay a profitable number of eggs she loses her head. It is not practical to cut off the heads of the workmen who do not produce a sufficient amount to earn their wage. Under the military form of shop management, if it is known positively that a workman's production is without profit to the organization, he is discharged. Under the modern form of scientific shop management the plan is to study the working conditions, and by standardizing the equipment and method of operation, and by training the workman, raise his efficiency.[3] This makes him a self-supporting unit of society, instead of a parasite, living on the production of his fellowmen. It benefits not only him and his employer, but the community in which he lives, and the world at large, by raising the standard of life in general, eliminating his share of waste, and helping posterity by creating a predisposition in his offspring to a higher degree of efficiency. Such effort to train the workman is parallel to that of the breeder of the hen, viz., to produce a strain that can and will lay the standard 200 eggs a year.

[3] Gantt, H. L., Work, Wages and Profit.

One Result of Standardization

The type faces, size of page, margins, paper, and binding of this pamphlet represent one of the standards we have established for scientific publications. This standard has been adopted by the following journals:

American Political Science Review
American Journal of Anatomy
Anatomical Record
Journal of Comparative Neurology
Journal of Morphology
Journal of Pharmacology and Experimental Therapeutics
Journal of Experimental Zoölogy
Phytopathology
Proceedings of the Entomological Society of Washington
Proceedings of the Philosophical Society of the University of Virginia
Proceedings of the Washington Academy of Sciences
The Plant World

Realizing the economy in cost of production as well as in library storage and binding which could be accomplished by establishing a typographical and mechanical style for scientific journals, the specifications represented by this pamphlet were adopted.

The question of paper was carefully investigated. The paper finally selected combined the essential qualities requisite for such work. Sufficient rag is used in combination with thoroughly washed sulphite to give wearing strength, permanency in texture and color, good printing qualities, neutral color and mellow surface for ease in reading, and opacity without a deteriorating amount of mineral filler.

The selection of types, type page, and margins was made to obtain legibility of text as well as a pleasing color tone of the whole.

The specifications finally adopted show the combined results of both typographical and paper experts, and certain modifications due to the valuable suggestions received from a number of the leading editors of scientific journals of the country.

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